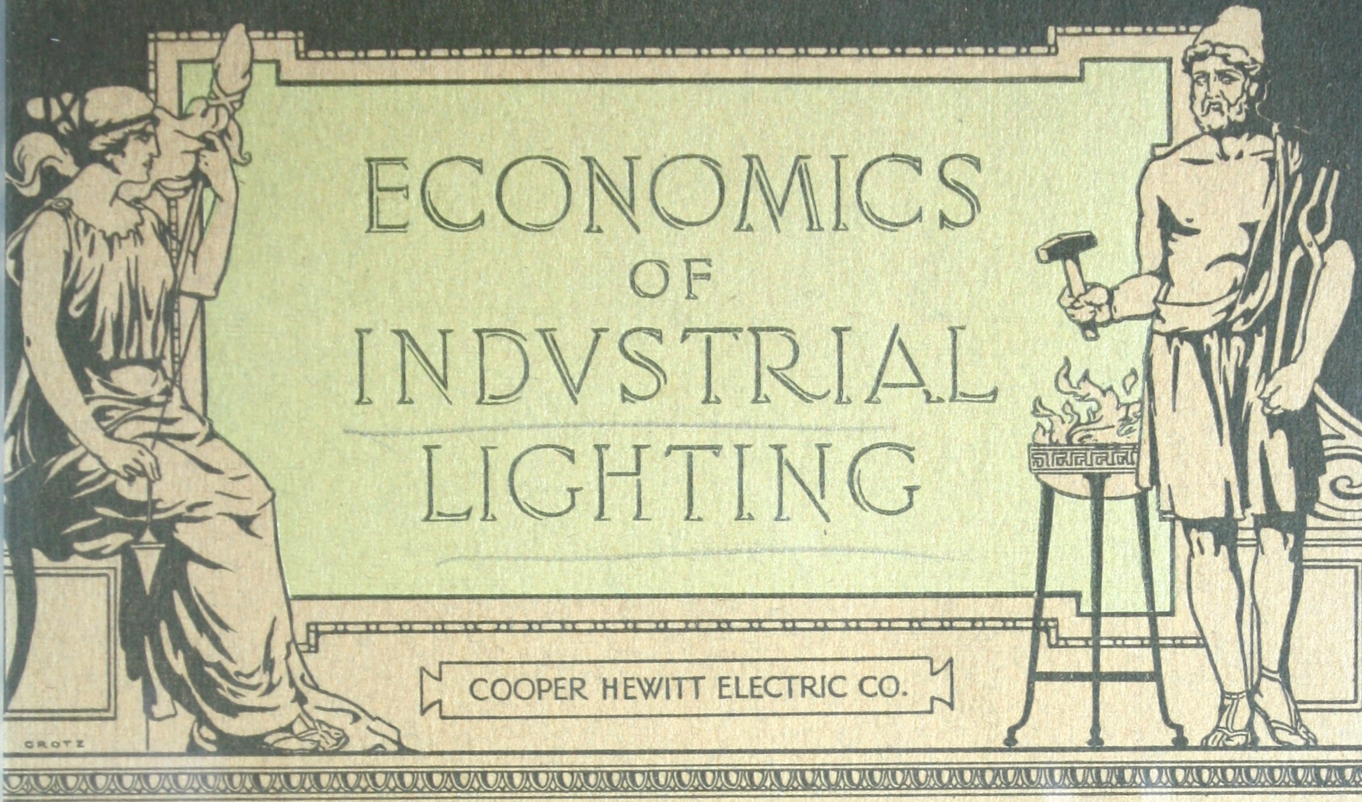


ECONOMICS OF INDUSTRIAL LIGHTING

COOPER HEWITT ELECTRIC CO.

ECONOMICS
OF
INDUSTRIAL LIGHTING

THE PRACTICAL APPLICATION

of the

PRINCIPLES OF ILLUMINATING ENGINEERING

TO THE LIGHTING OF FACTORIES,

SHOPS AND WORKS

as set forth by

THE HIGHEST SCIENTIFIC AUTHORITIES

COOPER HEWITT ELECTRIC CO.

HOBOKEN, N. J.

NOTE: The half-tone illustrations in the following pages are from unretouched photographs taken by the illumination of the Cooper Hewitt Lamps. This is shown by the fact that windows in every case appear dark, proving that there was no daylight whatever.

Industrial Lighting.

Introduction.

THE ORIGINAL "PRIME MOVER"

IN the early days of civilization human labor was employed to a large extent merely for the purpose of generating power. As the modern engineer would express it, man was used as a prime mover. Such work required no thought and no perception. To pull on an oar, or walk on a treadmill required only muscular action, and that of a kind so nearly automatic that it could be performed quite as well by the blind and the weak-minded as by those in full possession of their senses.

The first requisite of the laborer in ancient times was muscular strength and endurance. The prime requisites to-day are perception and judgment. As judgment is based upon perception, and as perception is mostly a result of sight, THE EFFICIENCY OF THE LABORER IS LARGELY DEPENDENT UPON THE COMPLETE AND ACCURATE FUNCTIONING OF HIS ORGANS OF VISION. To such an extent is this true that it may fairly be said that a workman is no better than his eyes. A blind workman and a dark factory are equally useless.

Light Is Cheaper Than Labor.

"FIGURE IT OUT YOURSELF"

THE manufacturer to-day has four things to consider: the Man, the Machine, the Light, and the Material; and the greatest of these is the Man. Human labor is still the preponderating item in the cost of every manufactured article in its final state.

The machinery cost probably does not often exceed 10% of the labor cost, and the average must be much nearer 5%.

The cost of light bears a still smaller ratio, one per cent. of the average daily wage being ample to supply the best kind of illumination for the workman's entire working day.

A few simple calculations will make this plain:

Suppose that electric current costs two cents a kilowatt-hour. One K. W. H. is equal to 100 watts for 10 hours. 100 watts of current used

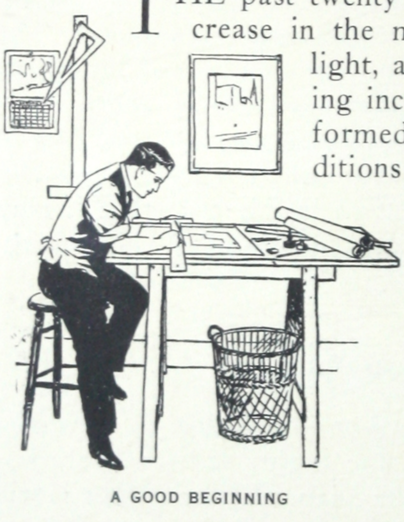
in the best form of modern electric lamps will produce an abundance of light for one workman, in fact, twice as much as will be required on the average. Two cents is 1% of $2.00, which is less than the average daily wage.

A skilled workman may easily receive 60c. an hour, and hence TWO MINUTES OF HIS TIME COSTS AS MUCH AS TEN HOURS OF LIGHT. Under good conditions the light which he would require could be produced for half that sum; so that we have the astonishing fact that ONE MINUTE OF A WORKMAN'S TIME MAY BE OF GREATER MONEY VALUE THAN THE COST OF THE ELECTRIC CURRENT NECESSARY TO PRODUCE THE LIGHT WHICH HE USES FOR AN ENTIRE DAY.

The results of this simple reckoning show how relatively unimportant is the cost of light compared to the cost of labor performed under it.

Illuminating Engineering, or Lighting as a Science.

THE past twenty years have witnessed an unprecedented increase in the means of producing and utilizing artificial light, and this has been followed by a corresponding increase in the kind and amount of labor performed by artificial illumination. These two conditions have led to the systematic study of the subject as a branch of applied science, to which has been given the name of Illuminating Engineering. This scientific study has resulted in establishing certain important facts, or laws relating to the use of light and the organs of vision.



A GOOD BEGINNING

The manufacturer who takes up the problem of selecting a method of illumination best suited to his particular needs finds himself confronted with the claims of the various makers of lamps and lighting accessories on the one hand, and the highly technical explanations of the professional illuminating engineer on the other. In order, therefore, to pass intelligently upon the arguments of the salesman and to appreciate professional advice it is necessary to have a general knowledge of the established principles of this new science.

It is the purpose of this booklet to give an explanation of the various principles involved in industrial lighting in the simplest and plainest language possible, and to verify these statements by quotations from the recognized authorities on the subject. It is hoped that this information may enable the manufacturer who has not given the matter special study to intelligently follow the recommendations of the professional illuminating engineer.

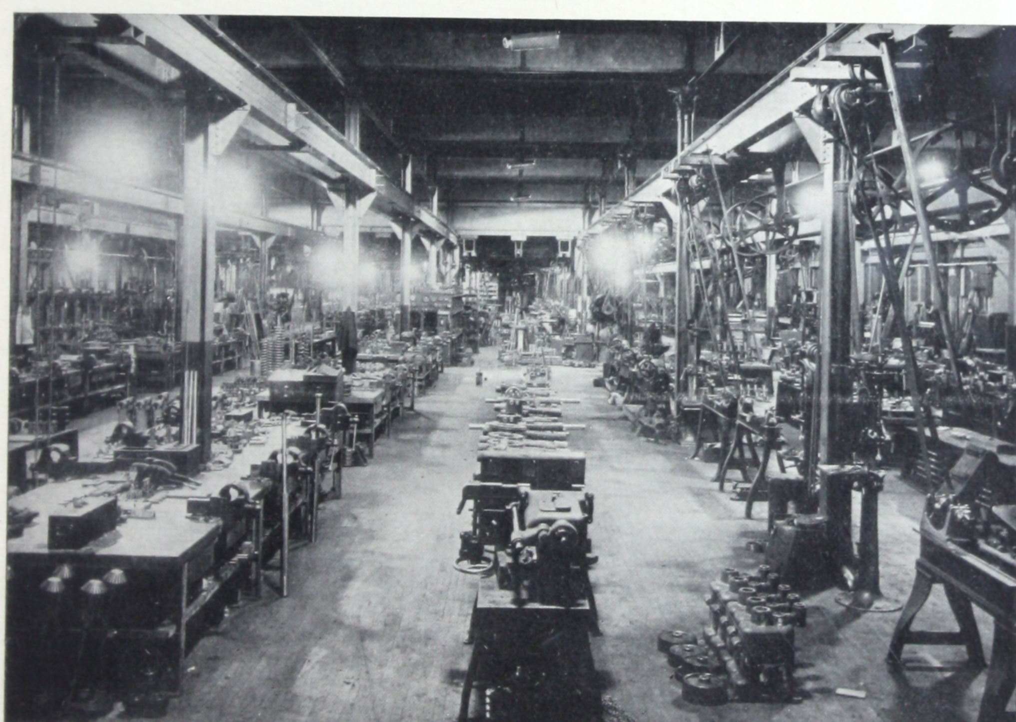
General Purpose of Illumination.

PRO BONO PUBLICO

IN many cases it is desired to have the lighting please the artistic sense as well as to afford vision, but in the industries the use of artificial light has but one simple object, namely: to enable the eye to perform its practical function of SEEING, with DISTINCTNESS AND EASE. The success of any industrial lighting system is to be judged solely by the extent to which it accomplishes this object.

DISTINCT VISION INVOLVES ABILITY TO SEE FINE DETAILS AND SMALL OBJECTS AT CLOSE RANGE WITH SHARPNESS AND PRECISION; TO DISTINGUISH OBJECTS AT A DISTANCE WITH ACCURACY; AND TO HAVE A CLEAR PERCEPTION OF ALL OBJECTS IN THE INTERMEDIATE SPACE.

Of course, the eye cannot see objects sharply in these three different fields at the same time, and it is frequently unnecessary to provide an illumination for all these purposes at once.



ROOM IN A MODERN MACHINE TOOL WORKS

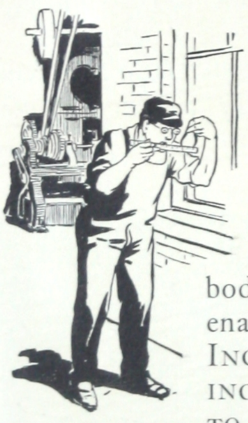
The modern machine shop is built and equipped with a single purpose in view,—securing the maximum output from the machinery and men. Cooper Hewitt light is the only illumination which has proven fully equal to daylight in accomplishing this purpose.

EASE OF VISION IS THE ABILITY OF THE EYE TO PERFORM ITS WORK CONTINUOUSLY FOR THE NORMAL LENGTH OF TIME WITHOUT UNDUE FATIGUE, STRAIN, OR IRRITATION.

Distinct vision does not necessarily imply easy vision. Conditions under which the eye may see with distinctness may be such as to result in excessive strain and fatigue if endured for any considerable length of time. Particular attention should be given to this fact in selecting a method of lighting for any given purpose.

In making comparative tests the results can only be fairly judged after the various methods have been used under the regular working conditions for a sufficient length of time to show their full effect upon the eyes. A hasty or incomplete trial is worse than useless.

Conditions of Distant Vision.



"THE LIGHT THAT FAILED"

IF you were asked, What is the first condition for seeing plainly? you would undoubtedly answer offhand, "an abundance of light." While this answer is true in the main, it is subject to a number of very important qualifications. It is quite possible to have a flood of light and yet the eye be able to see only with difficulty and strain. Working in too much light tires the eye, just as working in too much heat tires the body. There is a certain degree or intensity of light which enables the eye to see with the maximum sharpness and ease. INCREASING THE INTENSITY BEYOND THIS POINT NEITHER INCREASES THE APPARENT BRILLIANCY, NOR THE ABILITY TO SEE, and is therefore not only a waste of light but an actual burden to the eyes.

On this point PROF. YERKES* makes the following statement:

"The habit of working in illuminations which are too weak we recognize as bad. Nevertheless it is not rare. The habit of working—and of insisting that one cannot otherwise work satisfactorily—in illuminations which are too strong, is equally harmful and even more common perhaps than the other."

The eye sees objects by the light which they reflect, and hence dark-colored objects must receive a great deal stronger light in order to make them plainly visible. For example, five times as much light should be thrown on black cloth to enable one to see for sewing that would be required in the case of white cloth; and proportionate variations are necessary for other degrees of reflecting power, depending upon shades of color. This is one of the conditions which must be very carefully considered in determining the amount of light required for clear vision.

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*ROBERT M. YERKES, PH. D. Assistant Professor of Psychology, Harvard University; lecturer on "The Psychological Aspects of Illuminating Engineering" in the Johns Hopkins course, from which quotations are made.

Effect of Glare.


EYE STRAIN

A TOO high intensity of general illumination, however, is a fault much less frequently found than a too brilliant light in one spot or place. The latter gives rise to the effect called glare, which is the most conspicuous and serious evil of modern illumination.

Glare results from:—

(1) Light sources of excessive (dazzling) brilliancy placed within the range of the eye.

(2) Direct reflection of such dazzling sources from shiny or polished surfaces.

Dr. Cobb gives a very practical definition of glare, as follows:—

"The definition we propose to use here is a paraphrase of the famous definition of dirt: 'Dirt is matter out of place.' We shall here define glare as 'Light out of place.' It is trite to say

HAND PRESS ROOM, U. S. BUREAU OF ENGRAVING AND PRINTING

It is a literal fact that more money is made by using Cooper Hewitt light than by all other lights combined. The illustration shows a section of the hand press room in the Bureau of Engraving and Printing, Washington, D. C., the largest and best equipped steel engraving establishment in the world. Cooper Hewitt light was adopted after the most rigid tests extending over a number of years. The combination of microscopically fine detail with highly polished steel surfaces forms a problem in which acuity of vision and avoidance of glare reach an importance not to be found elsewhere throughout the whole field of human industry. Cooper Hewitt light has solved the problem to the full satisfaction of both operatives and officials.

that light is essential to vision, that without light vision is not possible. We can, however, add that under certain circumstances light entering the eye (as when looking at objects beyond a light-source) may be inimical to vision and enunciate a general proposition that glare is embarrassment of the eyes or vision associated with strong light sensations."

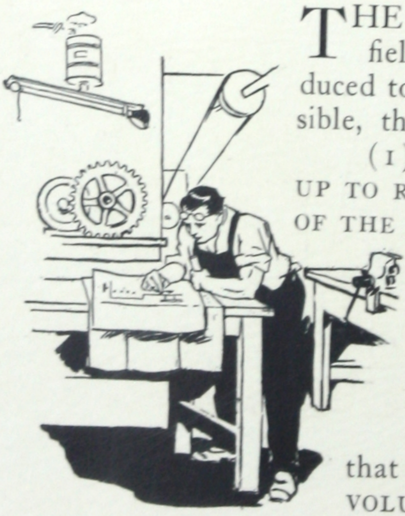
To the question, Under what conditions may light be considered out of place? DR. COBB* makes the following reply:

"Light in the field of vision not from the object of vision, and of an order of intensity disproportionately large."

On the effect of such misplaced light, the same authority further says:

"The simplest illustration of this is the light-source in the field of view, which cuts off the vision of objects of relatively low illumination beyond it. A light-source in the field of vision is always an invitation for direct vision. There is always a tendency to look directly at the light-source. This is best seen in children, perhaps, but is nevertheless, even in those that habitually resist it, a potent factor in disturbing fixation of vision on the object we wish to look at. In this way, the same amount of light coming to the eye from a source of small area is much more of an object to fasten the attention than a large one." * * * * * "Much light in the field of vision has a direct tendency to obscure the details in the relatively less luminous parts of the field of view, as we can easily verify by the simple experiment already mentioned of looking at the objects beyond a light-source."

How Glare Can be Reduced to a Minimum.


NO GLARE—NO GLASSES

THE evils of glare resulting from light in the field of vision as above set forth may be reduced to a minimum by carrying out, so far as possible, the following rules:

(1) PLACE ALL LIGHT-SOURCES HIGH ENOUGH UP TO REMOVE THEM FROM THE ORDINARY RANGE OF THE EYE.

(2) USE AS SMALL A NUMBER OF LIGHT UNITS AS POSSIBLE.

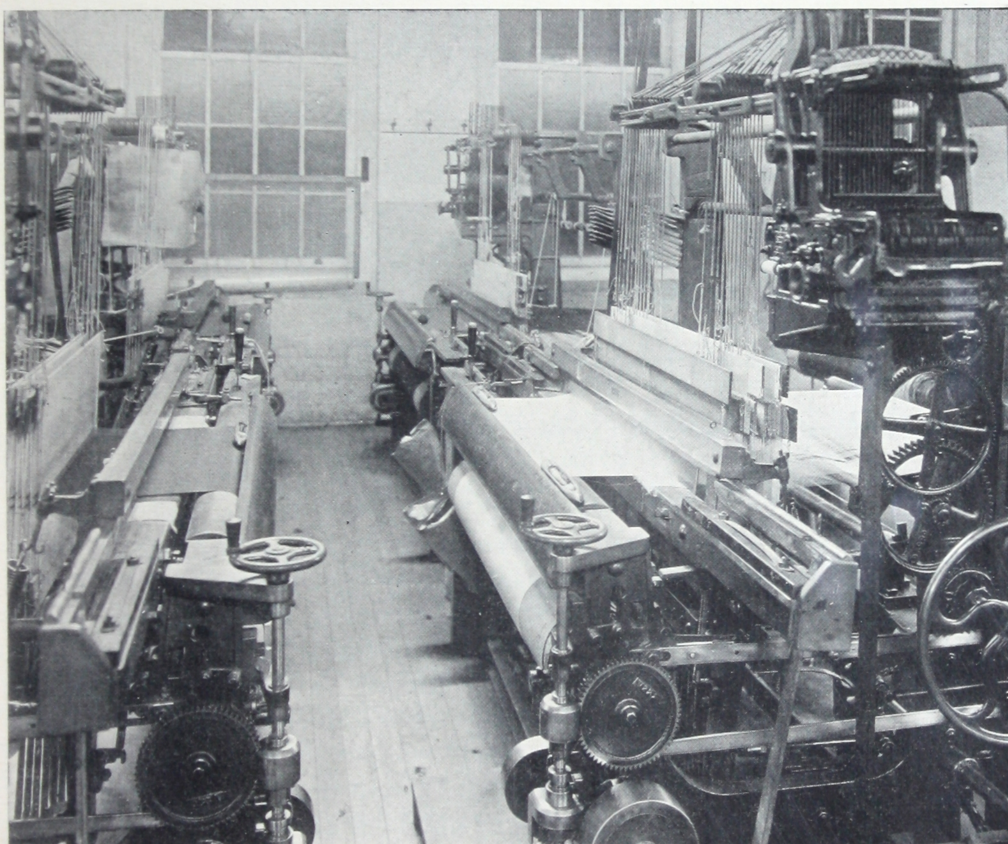
(3) USE LIGHT-UNITS HAVING THE LARGEST POSSIBLE AREA OF LUMINOUS SURFACE.

In order to observe these rules it is evident that the light-unit must give a relatively LARGE VOLUME of light, so that it will not be lost in the natural spreading out of the rays which results from placing the source at a considerable distance above the eye.

*PERCY W. COBB, B. S., M. D. Physiologist in the Research Laboratory of the National Electric Lamp Association, Cleveland; lecturer on "The Physiological Aspects of Illuminating Engineering" in the special course of lectures given at the Johns Hopkins University under the joint direction of the University and the Illuminating Engineering Society, November, 1911, from which lecture the quotations are made.

As every light-source is a point of attraction and distraction to the eye, THE LESS THE NUMBER OF UNITS USED, providing an evenly distributed illumination is secured, THE LESS WILL BE THE INTERFERENCE OF VISION from this source.

Even more important than the position of the light-units is the brilliancy of the luminous surface. This depends upon the QUANTITY OF LIGHT GIVEN OUT (TOTAL FLUX) IN PROPORTION TO THE AREA OF THE SURFACE FROM WHICH IT EMANATES. It is measured by the candle-power intensity per square inch of surface. This quantity is known as INTRINSIC BRILLIANCY. The comparative brilliancies of the various light-sources now in common use have been determined by careful scientific measurements, and are given on the following page.



LOOMS FOR WEAVING BROAD SILKS

The manufacture of silk fabrics involves the handling of materials in the most minute form known to industry. The original thread spun by the silk worm is no more than 1/10,000 of an inch in diameter; and in the weaving of fabrics there may be as many as a thousand threads to the inch. The vision of the operatives must therefore be sharp far beyond the ordinary demands of craftmanship. The increased acuity of vision produced by the characteristic blue-green color of Cooper Hewitt light is equivalent to a magnification of from 2 to 3 diameters. This explains the fact that the best weavers actually prefer Cooper Hewitt light to daylight, finding that they can do more and better work with less fatigue. The illustration is from one of the largest and finest silk mills in the world, which has used Cooper Hewitt light exclusively for the past ten years.

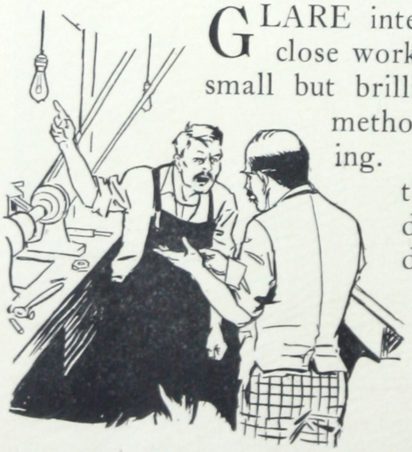
Intrinsic Brilliancy of Different Light Sources in Candle-Power per Square Inch.

Magnetite Arc	4000
Flaming Arc	5000
Tungsten 1.25 w. p. c.	1060
Gas filled	2000
Carbon 3.5 w. p. c.	400
Welsbach Mantle	31
Cooper Hewitt	14.9
Kerosene Flame	9

All authorities on the subject agree in their warning against the use of brilliant light-sources in such a manner that they must be encountered by the eye in seeing the objects for which the illumination is provided. Thus, Prof. Yerke: says:

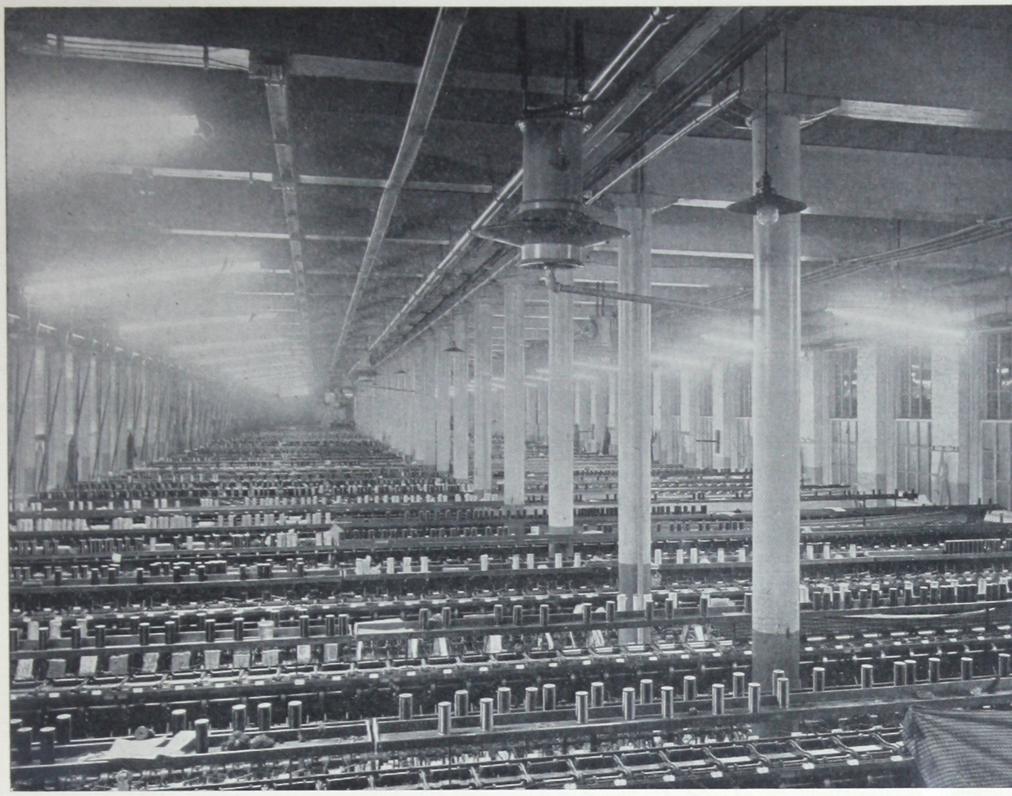
"Who of us, for example, has not been annoyed, if not actually inconvenienced, by the high intrinsic brilliancy of our sources of light. My study desk is illuminated by a tungsten lamp toward which I may not look without having my visual sensitiveness markedly diminished and without experiencing an annoying negative after-image. This state of affairs cannot be excused nor in any measure justified by the fact that the sun is brilliant; for we aim no less to surpass, or improve upon natural conditions of seeing, than to imitate them. And at this point we must frankly admit that the ideal artificial illuminant may ultimately prove to be very different in quality and in optimal intensity from the light of the sun. Evidently we may expect of the illuminating engineer such placing of lamps as shall minimize the undesirable effects of high intrinsic brilliancy. If lamps of high intensity are to be used they should be hidden and so placed that their light shall be delivered diffusely and in adequate controllable amount to the space to be illuminated."

Faults of Individual Lighting.


LABOR TROUBLES

GLARE interferes with vision at all distances. For close work it was formerly common practice to use a small but brilliant light-source near the operative,—the method known as "individual," or "special" lighting. It is very difficult to place a light-unit in this way so as to avoid having the rays shine directly into the eyes at short range, a condition which is not only extremely annoying but positively dangerous.

Much effort has been made to design reflectors which will protect the eyes from the glare of individual lamps; but while it is possible to cut off the direct rays, the glare from reflection is often quite as objectionable. All polished or "shiny" surfaces, such as newly worked metals, especially if oily, print type, glazed paper, silk fabrics and the like, give very powerful reflections, almost like a mirror, and these not only seriously interfere with distinct vision of the objects, but are very irritating to the organs of vision.



SKEIN WINDING ROOM, SILK MILL

The skein winding department of a silk mill affords a case in which absolute uniformity of illumination throughout the entire room must be combined with the utmost visual acuity and freedom from both glare and deep shadows. This exceptionally difficult problem has been completely solved by the proper installation of Cooper Hewitt Lamps, so that it has been found entirely practical to operate this department "double turn," the night production being fully up to that turned out during the day.

On this point Dr. Cobb observes:

"We must not forget than an object with reflecting surfaces, such as a piece of machinery, will present to the eyes many images of light-sources which itself may be well screened from the eyes. These images, although of a lower brilliancy than the light-source itself, may be very disturbing to vision by reason of their situation near the center of the visual field."

Mr. Marks* lays particular stress upon this point, and cites an example by way of emphasis:

In practice, we find on all sides serious results from the direct reflection of light from objects viewed; be it in the library of a palatial residence in which the library table is fitted with a polished plate-glass top, or in a factory in which the workmen handle highly polished pieces in the assembling of apparatus or face highly polished portions of machines, the baneful influence of regular reflection may be noted. In many cases the excessive regular reflection is due to faulty illuminating engineering.

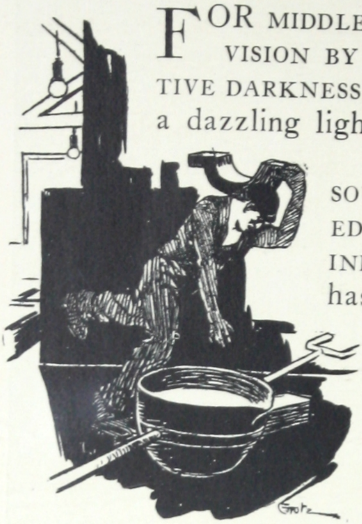
"In one instance in actual practice it was found in a factory that direct

*Louis B. Marks, B. S., M. M. E. Consulting engineer, New York; first president of the Illuminating Engineering Society; lecturer on "The Principles and Design of Interior Illumination" in the Johns Hopkins course, from which lectures quotations are made.

reflected light which reached the eyes of an operator who was at work on polished material was almost 40% of the light which reached the object viewed. When this direct reflection was cut down by a change in the installation, the operator could see the work much better and with less visual fatigue."

Glare a Cause of Industrial Accidents.

FOR MIDDLE AND FAR DISTANCES GLARE INTERFERES WITH VISION BY THROWING THE BACKGROUND INTO COMPARATIVE DARKNESS. The simple experiment of trying to look past a dazzling light furnishes sufficient evidence on this point.

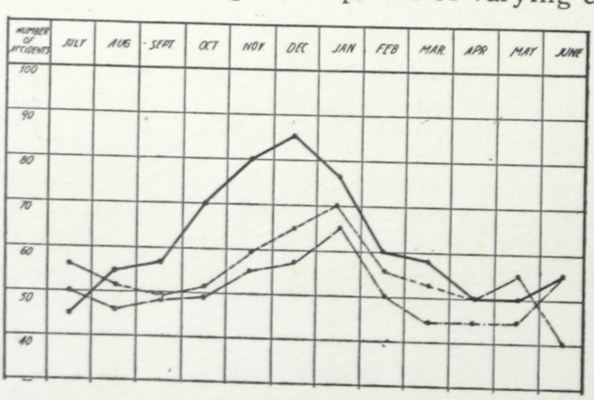


SAFETY LAST

THE DAZZLING OF THE EYE BY BRILLIANT SOURCES OF LIGHT IN THIS MANNER IS UNDOUBTEDLY ONE OF THE MOST FREQUENT CAUSES OF INDUSTRIAL ACCIDENTS. MR. JOHN CALDER* has collected statistics on industrial accidents in a very large number of cases, and his investigations show that the number of accidents bears a direct relation to the use of artificial light, being least in June when natural light is available for the longest time, and greatest in November when artificial light is most used. The number of accidents throughout the year, from the statistics which he obtained, is shown in the curve below.

On the relation of accidents to artificial lighting MR. CALDER says:

Insufficient lighting is a cause of numerous accidents, particularly serious and fatal falls. The author has observed that a maximum of accidents occur towards the close and beginning of each year, that is, during November, December and January, the months of minimum daylight. Fig. 1 shows the seasonal distribution for three successive years of about 700 deaths annually from industrial accidents which were reported with other injuries from an area embracing 80,000 plants of varying extents.



The influence of the duration and intensity of natural light in working hours on fatal and serious accidents is particularly noticeable in such founding, bridgebuilding, shipbuilding, engineering, and steel and iron works and other operations as have to be carried on within large spaces, often entirely in the open air and not easily illuminated artificially to the exclusion of deep shadows.

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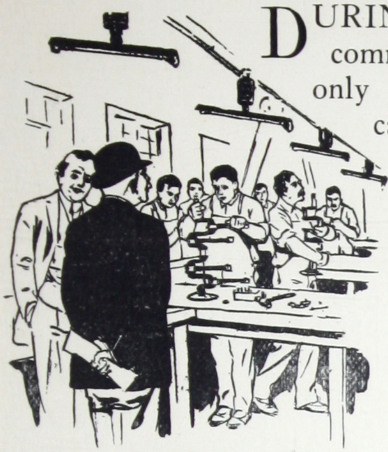
*JOHN CALDER, Supt. Remington Typewriter Works, Ilion, N. Y. The quotation is from a paper on "The Mechanical Engineer and the Prevention of Accidents," presented before the American Society of Mechanical Engineers.

Advantages of General Illumination.



"BETTER THAN DAYLIGHT"

DURING the first twenty-five years after the commercial introduction of electric light the only units available for general use were the carbon arc,—which is the most dazzling of all light-sources, as shown by the preceding table,—and the sixteen candle-power carbon filament incandescent lamp. It was thus practically impossible to produce a general illumination of sufficient intensity for close eye-work by means of units placed well up out of the range of vision. The arc lamp was too brilliant and too unsteady, and the incandescent lamp too small. Under these conditions individual lighting with incandescent lamps for each operative placed near the work was the lesser of the two evils.

LOCOMOTIVE ERECTING SHOP

The lighting of large works introduces a special problem in the placing of lamps, which must be above craneways and other obstructions. A general illumination of sufficiently high intensity to avoid the necessity of individual lamps, and so diffused as to eliminate deep shadows, is the ideal result to be obtained. The peculiarities of the Cooper Hewitt lamp enable it to fulfill all of these conditions to a degree equalled only by the best daylight. The illustration shows the remarkable distinctness with which this light brings out details, while giving a diffusion that renders objects plainly visible in the most shaded locations.

Mr. Calder calls attention to the faults of the old system:

Within plant buildings the intensity of artificial lighting at the cutting point of tools, for instance, and on very limited machine tool or bench areas, is frequently far above actual requirements and a source of much physical discomfort, while all around the operative a semi-darkness prevails which has a blinding effect in the sudden transitions of the vision required by his employment.

It has been found by exact photometric observations of shop-lighting conditions both during the day and at night, that the concentrated illumination by means of shades of ordinary 16-c. p. incandescent units on cutting tools in machines and the area near them is often several times the intensity of ordinary daylight on the same parts. It is very difficult to convince the operative that he is suffering from too much light at any place and the call is constantly for more light.

What is wanted from the safety point of view and also, the author believes, from considerations of power economy, is the elimination by good illuminating engineering of this excessive hard light on spots only, which causes eye-strain and poor vision of surrounding areas with resultant accident.

With the discovery by Dr. Peter Cooper Hewitt of the mercury vapor lamp, which possesses the steadiness of the incandescent lamp together with th lowest intrinsic brilliancy of all commercial light-sources, and gives a large total volume, or flux, of light, the former difficulties were removed, and for the first time it became possible not only to imitate daylight illumination, but as Prof. Yerkes suggests, TO ACTUALLY IMPROVE ON IT IN A GREAT MANY CASES. The method of individual lighting has been generally abandoned, and is being replaced by general illumination.

Importance of Diffusion.

A QUALITY of light which has a large influence in determining distinctness and ease of vision is that known as DIFFUSION. The meaning of the term can be best understood from examples. Daylight on a cloudy day is perfectly diffused; light rays of equal power come from all directions. Perfectly diffused light produces no shadows whatever. The beam of a searchlight has no diffusion; all of the light rays are in one and the same direction. Such light produces shadows with perfectly sharp outlines and of endless extent. Between these two extremes there is every variation in degree of diffusion which can be determined by the character of the shadow cast; THE MORE COMPLETE THE DIFFUSION, THE MORE INDISTINCT WILL BE THE EDGE OR OUTLINE OF THE SHADOW.

DIFFUSION DEPENDS UPON THE EXTENT OF SURFACE FROM WHICH LIGHT EMANATES. Thus, on a cloudy day it comes equally from the whole hemisphere of the sky, while in the case of direct sunlight it comes only from the visible disc of the sun.

METAL STAMPING WORKS

This illustration is typical of a difficult class of lighting problems which still have to be met, namely, buildings of the older form, with inadequate windows and crowded with machinery, shafting, belts, posts and other obstructions. In the case shown here Cooper Hewitt lamps were installed with due regard to location, and a general illumination produced which proved to be the full equivalent of daylight. In actual fact, the night production exceeded the day output,—a result of frequent occurrence with Cooper Hewitt illumination.

In artificial light-sources the carbon arc gives the least diffusion, since the light comes from a small spot on the ends of the carbon; while the Cooper Hewitt Lamp gives the highest duffusion, since the luminous surface is that of a tube an inch in diameter and from twenty to fifty inches long; that is, the visible luminous surface is from twenty to fifty square inches in area.

Diffused light is distinctly agreeable and easy to the eyes. Such light is commonly spoken of as "soft light," while undiffused light is spoken of as "hard light," or as being "hard on the eyes." The importance of this quality of diffusion is thus stated by MR. E. LEAVENWORTH ELLIOTT:—

"It is largely due to its high state of diffusion that daylight, even when vastly more intense than artificial illuminations is the easiest of all light on the eyes. It is a common and serious mistake in case of weak or overstrained eyes to reduce the intensity of the light instead of increasing the diffusion."

E. LEAVENWORTH ELLIOTT, B. S. Founder, and for six years editor of "The Illuminating Engineer." The quotation is from Foster's "Electrical Engineers' Pocket Book."

Shadows Necessary for Distant Vision.

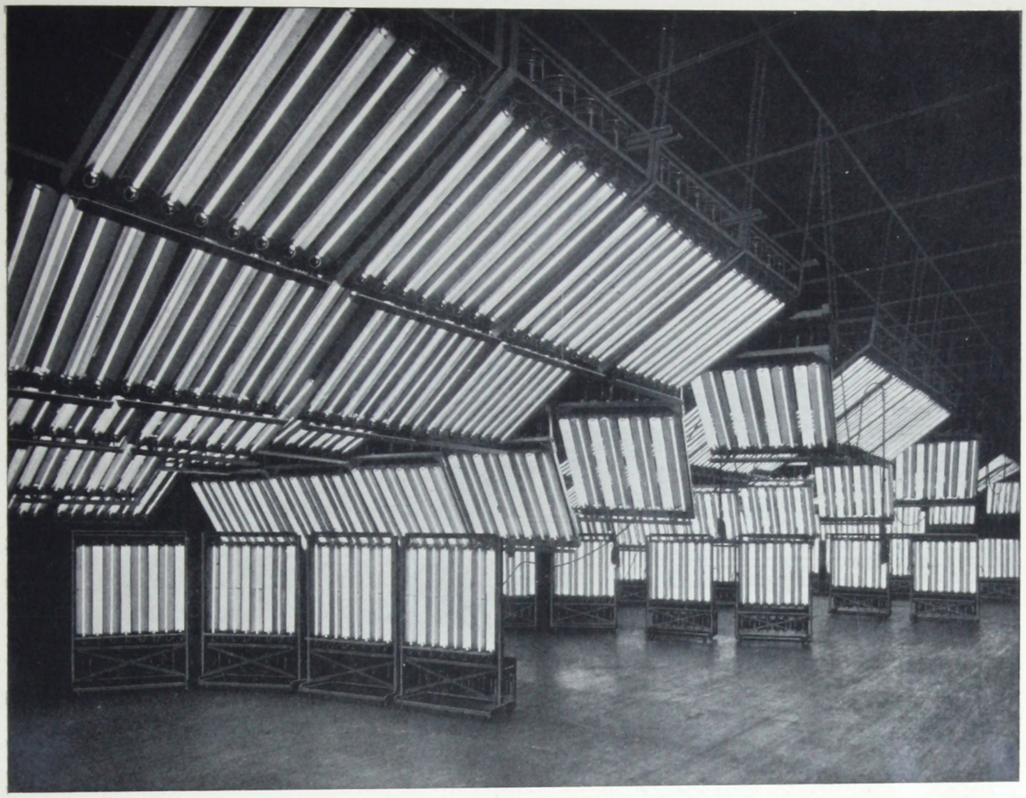
Perfect diffusion of light, however, is not conducive to distinct vision, since it eliminates all shadow, and it is shadow that produces the "relief" in objects, that is, makes them "stand out." To see objects other than flat surfaces distinctly shadow is therefore necessary. It must not, however, be either so intense as to hide the line of demarkation between the object and the shadow, nor so sharp in outline as to appear to be part of the object. In practice the best result is obtained, that is, THE OBJECT IS MOST CLEARLY SEEN WHEN THE SHADOW IS SUFFICIENT TO FULLY BRING OUT THE RELIEF WITHOUT BEING SO DARK OR SHARP AS TO OBSCURE THE DETAILS OF THE SUBJECT IN ANY PLACE.

MR. MARKS states the conditions thus:—

"For satisfactory illumination, it is necessary to have sufficient directed light to mark the edge of the object by their shadow and thereby improve the distincting, but at the same time there must be sufficient diffused light to see clearly in the shadows; that is to say, a proper proportion of directed and diffused light is necessary."

A MODERN FOUNDRY

The special problem in foundry lighting arises from the non-reflecting nature of molding sand, and the necessity of seeing clearly the interior of cavities. The scientific discovery by Purkinje, that the eye can see objects clearly by green light in what would be obscure shadow with ordinary light, explains the special fitness of Cooper Hewitt light for this purpose. It is a peculiar provision of nature that the light which gives special aid to the eye in its full brilliancy should lend equal aid in the dimness of shadow.



STAGE OF ONE OF THE LARGEST MOVING PICTURE STUDIOS

The production and exhibition of moving pictures now ranks fifth among the industries of this country. The great studios where the productions are staged for photographing depend upon Cooper Hewitt light for their illumination, finding it better than daylight.

"In drafting rooms, where all of the objects requiring distinctness are in one plane, and the distinction is exclusively by differences of color and intensity, but not by shadows, a perfectly diffused illumination is required, and noticeable shadows would be objectionable."

"In the use of shadows in illuminating engineering it is necessary for the outer edge of the shadow to blur or gradually to fade, and this result requires that the source of directed light should not be small, but should be sufficiently large to scatter the light at the outer edge of the shadow."

Mr. Marks cites the following example to show the advantage of general illumination of the proper degree of diffusion over special lighting, in which there is a minimum of diffusion:—

"A striking example of the relativity of illumination intensity required for a particular class of work was noted by me in a factory installation in which the operators had become accustomed to an intensity of approximately 20 foot-candles (215 meter-candles) on the work, and in which it appeared that this intensity was absolutely required to enable them to do the work clearly. In two cases under discussion the localized system of drop lamps was used, each machine being provided with 2 individual lamps, backed by opaque reflectors which shielded the eyes from the light of the lamp.

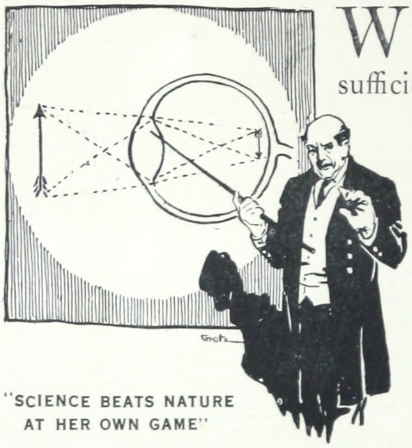
"It was found that by substituting a system of general lighting by which the entire room was moderately illuminated, while at the same time a considerable proportion of the light of the lamps was directed to the machine, the operators could actually see the work better, even though the intensity

of illumination on the work was reduced from about 20 foot-candles to from 4 to 6 foot-candles. The need of a high intensity with the local system of lighting, as first used in the factory was undoubtedly due primarily to the effects of the strong contrast in the intensity of illumination on different parts of the machine."

Sharp, black shadows, such as those produced by direct light from small, brilliant sources, are sources of danger scarcely less fruitful of industrial accidents than glaring light-sources in the line of vision, and should be rigidly avoided.

The diffusion of artificial light depends to a considerable extent upon the location and arrangement of the light-units, and upon the manner in which the units distribute their rays. These two points are considered under the general head of "distribution" by illuminating engineers.

Effect of Color on Distinctness of Vision.



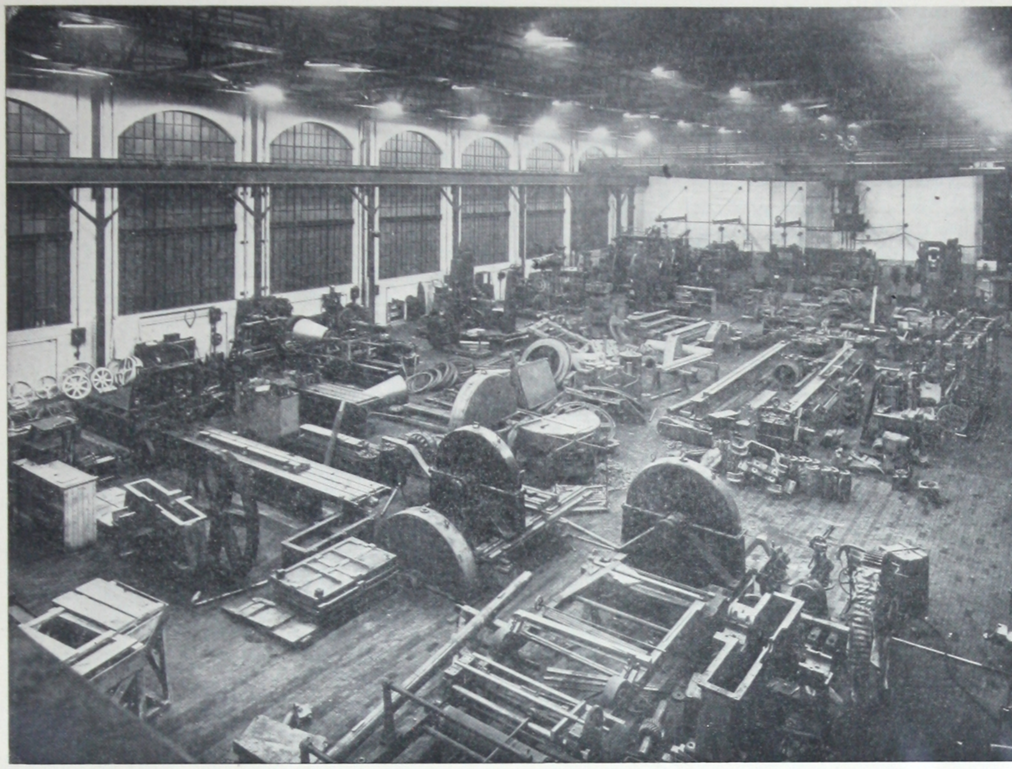
"SCIENCE BEATS NATURE AT HER OWN GAME"

WE have thus far seen that distinctness and ease of vision requires a steady light of sufficient intensity, well diffused and properly distributed. There remains one other important consideration, namely, the quality of the light itself, that is, the character of the radiations.

What we commonly think of as the eye, that is, the eye-ball, is an optical apparatus very similar to the photographic camera. It contains a lens in the front part, provided with a diaphragm, or stop (the iris, or pupil), a screen (retina), at the back for receiving the image produced by this lens, and a means of focusing the image for objects at different distances.

SHARP VISION IS THE RESULT OF A SHARP IMAGE ON THE RETINA, and anything which reduces the sharpness of this image reduces the sharpness of the visual impression correspondingly. Now, it is a well-known fact in optics THAT EACH OF THE DIFFERENT COLORS IS BROUGHT TO A DIFFERENT FOCUS BY A GIVEN LENS; in other words, if we focused accurately for RED LIGHT we would find the image OUT OF FOCUS and blurred by BLUE LIGHT. As daylight and ordinary artificial light is a compound, or mixture, of all the different color rays, it is evident that the single lens of the eye cannot focus them all sharply at the same time. As a matter of fact, THE EYE UNCONSCIOUSLY MAKES A COMPROMISE AND FOCUSES FOR THE GREENISH YELLOW RAYS. If, therefore, we have a LIGHT CONSISTING ONLY OF SUCH RAYS, or largely of them, the IMAGE IS MORE SHARPLY FOCUSED and vision correspondingly more accurate because there are no out-of-focus rays to blur the edges. Such light, then, increases the acuity, or sharpness of vision.

The first practical application of this fact was observed in the use of the approximately monochromatic (single-colored) light of the Cooper



ASSEMBLING FLOOR, GENERAL MACHINE SHOP

Daylight was formerly considered unapproachable in excellence because of its perfect diffusion, steadiness, and ease on the eyes. All of these qualities are now readily obtainable with Cooper Hewitt light. The illustration is an example of such lighting.

Hewitt Lamp, which was observed to MAKE FINE DETAILS STAND OUT WITH PECULIAR SHARPNESS, giving them the appearance of being actually magnified. While the cause of this effect was at once accurately predicted from the theory of optics, the matter has been thoroughly investigated by several competent scientists and the correctness of the theory fully established. The following extract from a report of experiments conducted by DR. LOUIS BELL,* PH.D., and DR. C. H. WILLIAMS, is taken from the *Electrical World* of May 11, 1911.

'The effect of the chromatic aberration is to make the violet rays come to a focus further to the front than the red rays, while the yellow and green rays take an intermediate position. In focusing by act of accommodation these intermediate rays of high luminosity are automatically brought into focus on the retina, the red focus lying behind it and the violet focus in front of it.

"The more nearly monochromatic the light effective in forming the retinal image the sharper in general that image must be. Hence in the case of artificial light which is strongly colored and therefore gives greatly pre-

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*LOUIS BELL, PH. D., Consulting Engineer, Boston. Past president, Illuminating Engineering Society; Author of "Art of Illumination" and several standard electrical works; a frequent contributor to the technical press. In collaboration with Dr. C. H. Williams, a prominent oculist of Boston, he conducted a very careful investigation of the effect of different colored light upon acuity of vision, the report of which was published in the *Electrical World,* from which article quotations are made.

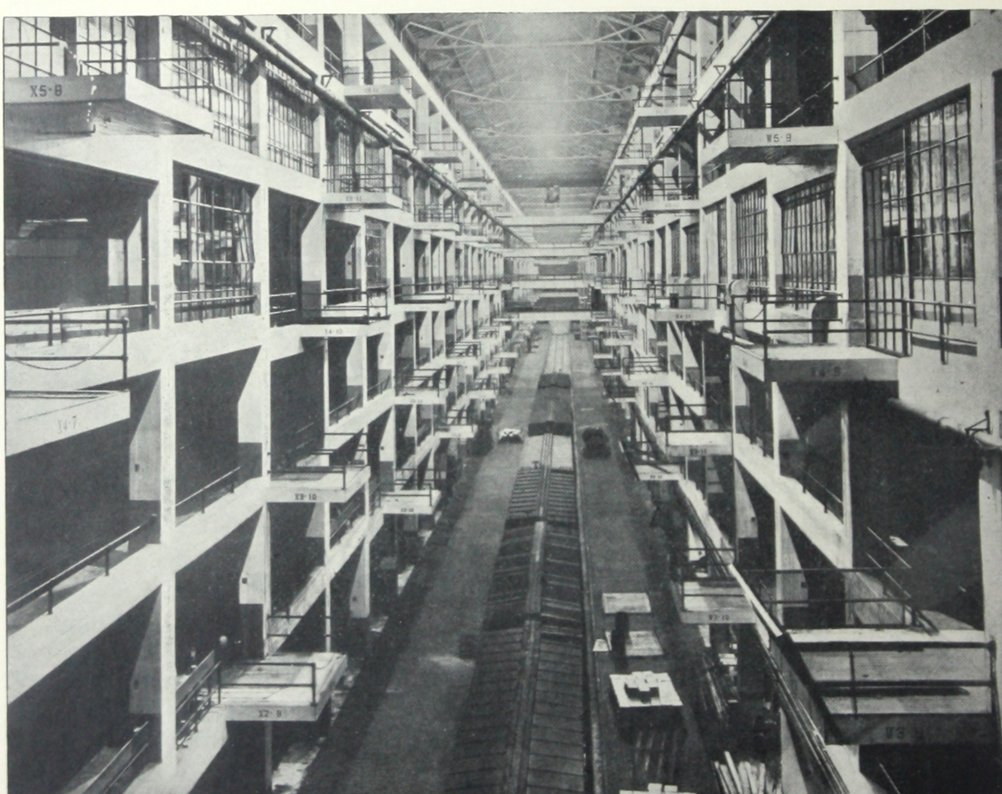
dominant luminosity in a comparatively narrow region of the spectrum, there should be more or less increase in the acuity of vision. Such distribution of luminosity is found in the light * * * of the mercury-vapor lamp.

"The low luminosity of the blue mercury line leaves the green lines enormously predominant, and in viewing objects illuminated by the mercury-vapor lamp the eye focuses itself with respect to these, which are sufficiently close together to give nearly coincident focal surfaces.

"Now, the real ratio between the luminous intensities as determined in the manner already described was as 1 is to 5.42. The apparent candle-power of the tube as determined by equal ease of reading was, therefore, on the average 1.95 times the actual photometric candle-power.

"There was a marked sense of sharper definition on the side of the mercury tube and several of the observers could only be persuaded by careful inspection that the type on this side was not actually larger than that on the other. There was also a perceptible added strain on the accommodation on the side of the tungsten lamp in making these judgments of acuity, the comparatively slight difference in focus being at once obvious.

"The writer's experiments merely make it apparent that a nearly monochromatic light has, through its great reduction or chromatic aberration, a power of revealing detail considerably greater than its photometric intensity would indicate. It acts as if it were a light of much higher candle-power than it really is."



STOCK ROOM IN A WELL KNOWN AUTOMOBILE WORKS

The unusual height as well as the extent of this department of a concern turning out 1,000 automobiles a day introduced a difficult problem in lighting, which the installation of Cooper Hewitt lamps, as shown, has solved with eminent satisfaction.

Effect of Color on Distant Vision.

"OLD TIMERS"

THE color of light also has a very decided effect upon the distance at which objects can be distinguished. The facts in the case are stated by DR. STEINMETZ,* as follows:

"For illumination of very high intensity the maximum physiological effects take place in the yellow light, while for very low intensity of illumination it occurs in the bluish green light; that is, at high intensity yellow light requires less power for the same physiological effect than any other color of light, while for low intensity, bluish green light requires less power for the same physiological effect than any other color of light. Thus, if an orange yellow light, as a flame carbon arc, and a bluish green light, as a mercury lamp, appear of the same intensity from the distance of 100 feet, by going nearer to the lamps the orange yellow appears to increase more rapidly in intensity than the bluish green, and from a very short distance the former appears glaring bright, while the latter is disappointing by not showing anywhere near the same apparent intensity. Inversely, when going further and further away from the two lamps the orange yellow light seems to fade out more rapidly than the bluish green, and has practically disappeared while the bluish green is still markedly visible. A mercury lamp, therefore, can be seen from distances from which a much brighter yellow flame arc is practically invisible, but inversely from a very short distance the yellow light appears dazzling, while a mercury lamp of higher candle-power appears less bright.

"For bluish green light, however, the sensitivity is high at low and moderate intensities but falls off for high intensities, while for orange yellow light the sensitivity is high at high intensities and falls off at medium and low intensities and ultimately vanishes, that is, becomes invisible at intensities many times higher than those at which green light is still well visible.

"At the limits of visibility the eye is very many times more sensitive to green light and in general, high-frequency light, than to orange yellow, and in general, low-frequency light."

The above explanation accounts for the ability to see objects that are in complete shadow, that is, where the direct light is entirely cut off and the illumination is only by the light reflected from other objects.

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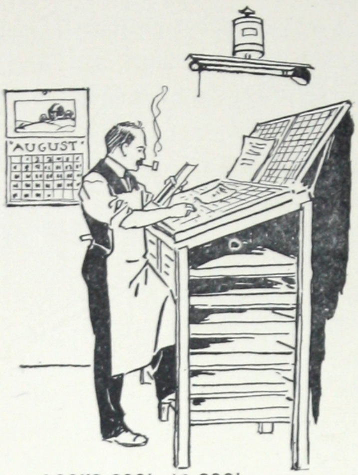
*CHARLES P. STEINMETZ, PH. D. Consulting engineer to the General Electric Company, Schenectady; professor of electrical engineering, Union University; author of "Radiation, Light and Illumination," from which quotations are made. Dr. Steinmetz's writings cover the entire subject of electricity and are considered classics in their line.

Effect of Color on Ease of Vision.



LOOKS COOL, IS COOL

FINALLY, the color of light plays an important part in the ease of vision. The effect of colors is psychological as well as physiological. The following quotations from PROFESSOR YERKES on the psychological aspects of illumination will be of interest:

"In the contrast of our attitudes toward colors, we find splendid instances of chance agreeable or disagreeable experiences as well as of ingrained prejudices, and agreeable or disagreeable sentiments. We come to like or dislike colors much as we do taste or color experience, and it is sometimes extremely difficult for us to educate ourselves out of these acquired affective attitudes toward colors."

"With the acquisition of definite knowledge concerning the practical and esthetical values of lights and colors there come modifications of tastes. At present it is fairly certain that the common attitude toward yellowish illuminants is the result of habit and that many of us might readily educate ourselves to a like appreciation of certain chromas and tints of other hues. * * *

"The lesson taught alike by the physiology and the psychology of red is that it should be avoided in general illumination, and used only for special purposes with full knowledge of its effects upon the organism. * * * *

"The psychology of yellow is of peculiar interest because the majority of our artificial illuminants are yellow. Savages and children are said to be fond of yellow and it seems probable that this attitude toward it is the natural human attitude. Yellow is of high illuminosity and it lacks the peculiar, and not wholly desirable stimulating characteristics of red." * * *

"Blue is a cold, restful color. We shall consider it in connection with violet because of fundamental likeness. The illuminosity is low as compared with that of yellow and green, and they therefore make poor hues for general illumination. In general the effect of the use of blue and blue-violet lights is depression. They are pleasant because of their restfulness and coolness, and for this reaon may to advantage be used decoratively."

"The color green is, under circumstances, very unpleasant; under others it is as markedly pleasant. In nature it plays an important role as the prevalent earth color, except in arid regions. Perhaps it is this very fact, and the habits of seeing and feeling which it has established in us, which renders green a disagreeable color for general illumination. The mercury vapor lamp, the old Welsbach, and all other sources of light of a distinctly greenish hue are more or less under disfavor. Their light is at first distinctly disagreeable to most individuals. But what is of chief interest in this connection is that there are circumstances which indicate the use of a greenish light. I have in mind an instance of excellent effects from the use of mercury vapor lamps. An automobile salesroom, which I have especially observed because of the agreeableness of the illumination, exhibits these lamps well placed and efficiently as well as agreeably illuminating a space which, because of its decoration would seem to be difficult of satisfactory illumination."

DR. STEINMETZ has explained the physiological side of the subject with his usual simplicity and clearness:

"Radiation is a form of energy, and when intercepted and absorbed, disappears as radiation by conversion into another form of energy, usually heat. Thus, the light which enters the eye is converted into heat, and if its power is considerable it may be harmful or even destructive, causing inflammation or burns. This harmful effect of excessive radiation is not incident to any particular frequency, but inherent in radiation as a form of energy. It is, therefore, greatest for the same physiological effect, that is, the same amount of visibility, for these frequencies of light which have the lowest visibility or highest power equivalent, that is, for the red and the violet and least for the green and the yellow. Hence, green and greenish yellow light are the most harmless, the least irritating to the eye, as they represent the least power. We feel this effect and express it by speaking of the green light as 'cold light' and of the red and orange light as 'hot' or 'warm'. The harmful effect of working very much under artificial illumination is largely due to this energy effect, incident to the large amount of orange, red, and especially ultra-red in the radiation of the incandescent bodies used for illuminants and this does not exist with 'cold light' as the light of the mercury lamp."—Electrical World.

BODY FINISHING DEPARTMENT, AUTOMOBILE WORKS

Cooper Hewitt light has demonstrated its superiority in the painting and body finishing departments of the automobile industry on account of its ease on the eyes and the sharpness with which it brings out any defects in the finish.

Efficiency.

THE 99% EFFICIENT LIGHTING SOURCE—EMITS GREENISH-YELLOW LIGHT

THE word "efficiency" has been so freely used of late that it has fallen into the class of "glittering generalities." When it is found in connection with "light" or "illumination" therefore it is well to scan the context closely so as to avoid misapprehension.

Efficiency may refer to a light SOURCE or to a lighting SYSTEM; and it may be PHYSICAL (electro-mechanical) or VISUAL efficiency.

THE PHYSICAL EFFICIENCY OF A LIGHT-SOURCE is the ratio of the energy (power) expended to the quantity of *light* produced, and is stated in watts per candle, or more correctly, in watts per lumen. It shows the efficiency of the particular device, called a *lamp* as a converter of electricity into light.

THE PHYSICAL EFFICIENCY OF A LIGHTING SYSTEM is the ratio of the energy expended to the illumination produced. The illumination of an imaginary surface thirty inches from the floor is understood, unless otherwise specified. The measurement is expressed in watts per foot-candle per square foot, and takes into account all the accessories used in distributing and diffusing the light of the lamps, and reflection from ceiling and side walls.

THE VISUAL EFFICIENCY OF A LIGHT-SOURCE is the comparative ease and distinctness with which the eye can see by the light, when properly used. Visual efficiency depends upon the color-composition of the light, being greatest for greenish-yellow, followed by yellow, green, red, blue, and violet, in descending order.

The visual efficiency of a lighting system is determined by the ease and distinctness with which the eye can see by the *illumination* produced. This involves all of the principles of lighting, such as intensity of illumination, glare, density and location of shadows, etc. It is wholly incapable of numerical measurement, but even more important than the visual efficiency of the light-source alone.

It will be seen that none of the preceding definitions of efficiency include the *fitness,* or suitability of a method of illumination to the purpose which it is meant to serve. It would simplify matters very much to consider all efficiencies under two general heads, viz: *proximate* efficiency, and *ultimate* efficiency. The former would then include any kind of efficiency capable of mathematical expression, while the latter would express the degree of completeness with which the illumination fulfilled its entire purpose.

A logical division of the entire field of illumination is likewise into two classes: Social Lighting and Industrial Lighting. The latter includes all that part of the field in which manual labor is the paramount human activity; the former includes that part of the field in which mental activities or social amenities predominate.

According to this terminology the ultimate efficiency of an industrial lighting system could be measured with a fair degree of mathematical accuracy as the ratio of the output, or product of the labor performed under the given illumination to that produced under the best daylight illumination.

The cost of producing light has been reduced to a point which renders all considerations of proximate, or physical efficiency a matter of interest only to the scientific investigator.

The several forms of electric arc, and the carbon filament lamp are rapidly becoming obsolete, and have scarcely more than an historic interest today. Experiments by Drs. Bell and Williams (pp. 20) show that the visual efficiency of the Cooper Hewitt glass tube lamp is practically double that of the comparatively white light of filament lamps. While no determinations were made of the light of the quartz tube lamp, it probably has fifty per cent. greater visual efficiency.

High Efficiency of the Cooper Hewitt Lamp Explained.

The scientific reason for THE HIGH EFFICIENCY OF THE MERCURY VAPOR LAMP IS TO BE FOUND IN THE SIMPLE FACT THAT IT WASTES LESS OF THE ELECTRICAL ENERGY IN THE GENERATION OF HEAT; in other words, it is nearer to the theoretical "cold light."

DR. HYDE* gives a clear explanation of the matter:

"The temperature of the mercury arc in a glass tube is apparently quite low, and the explanation of the efficiency is ordinarily ascribed to lumiescence, with a relatively large part of the energy in the visible spectrum. The efficiency of the arc, as ordinarily operated, is variously given as ranging between 12 and 24 lumens per applied watt, corresponding to 0.5-1.0 watt per mean spherical candle. By using quartz instead of glass it is possible to operate the lamp with a much higher current density and greatly increased efficiency. It is probable that an efficiency of about 50 to 60 lumens per watt, corresponding to 0.20 or 0.25 watt per mean spherical candle, may be reached in the case of the quartz arc. It is believed, in this case that at high temperatures pure temperature radiation of increasing efficiency supplements the decreasing efficiency of the luminescent radiation." * * * *

"In the process of light production by the passage of an electric current through the filament of incandescent lamps we commonly say that the electric energy is transformed into heat, and that the filament is heated to such a temperature that it becomes incandescent. On the other hand, in the case of the luminous vapor in the arc discharge, we frequently say that the vapor radiates by luminescence, and that there is a direct transformation of electric energy into radiation without the intermediate form of heat energy."

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*EDWARD P. HYDE, PH.D. Director of the Research Laboratory of the National Electric Lamp Association, Cleveland; past president of the Illuminating Engineering Society; late physicist for the National Bureau of Standards, Washington; lecturer on "The Physical Characteristics of Luminous Souures" in the Johns Hopkins course, from which lectures quotations are made.

Conclusion.

THE preceding pages contain the basic facts in regard to artificial light in its application to industrial illumination. The subject is a broad one, resting upon scientific laws, and this survey is necessarily condensed. Anyone who has the time and inclination can verify every statement made by reference to the recognized experts in the various phases, and by the practical experiences of those who have to work by artificial light, and of those who are responsible for furnishing light for these purposes.

We are now justified in applying these principles to determine the merits of the COOPER HEWITT LAMP as a source of illumination for industrial purposes. Let us begin with a brief description of the lamp.

The standard Cooper Hewitt lamp consists of a glass tube one inch in diameter and from twenty to fifty inches long, having one end enlarged into a bulb for holding mercury, and a small iron cup at the other. The mercury and the iron cup serve as electrodes, or carriers of the electric current, which is supplied to them through wires hermetically sealed into the glass. The air is carefully exhausted from the tube. When the electric current is caused to pass from one electrode to the other it vaporizes a small quantity of the mercury, which fills the tube and is rendered luminous by the passage of the current.

THE COOPER HEWITT LAMP THUS DIFFERS RADICALLY FROM ALL OTHER COMMERCIAL LIGHT-SOURCES, IN THAT IT GIVES OUT ITS LIGHT

In addition to the tube there are the necessary electric accessories for starting the flow of current when the lamp is turned on, and maintaining it in steady operation. The lamp needs no regular "trimming," or attendance, except to occasionally wipe off the tube and reflector as dust may accumulate, the same as windows require occasional cleaning.

The tubes eventually become inoperative, but only after very long use, generally measured in years. When this occurs they are easily and quickly replaced.

The light produced by the glowing vapor differs radically from that produced by other means. It contains practically no red rays, most of the light being yellow, with a fair addition of green and blue, thus giving it the peculiar peacock-blue color which is now familiar to all. THIS PECULIAR COLOR COMPOSITION OF THE LIGHT GIVES IT DISTINCT AND FROM A LUMINOUS GAS, WHEREAS IN THE OTHERS THE LIGHT IS EMITTED FROM A GLOWING SOLID.

IMPORTANT ADVANTAGES FOR ALL INDUSTRIAL PURPOSES, (except the few cases in which it is necessary to match colors by their daylight values) as follows:

(1) IT INCREASES ACUITY OF VISION, that is, enables the eye to see small objects and fine details with greater sharpness than ordinary white light.

(2) IT ENABLES THE EYE TO SEE DISTINCTLY WITH CONSIDERABLY LESS INTENSITY OF ILLUMINATION, that is, in a much dimmer light, and therefore renders objects visible in shadows where they would be indistinct with ordinary light.

(3) IT IS THE EASIEST ON THE EYES, that is, the eyes can see with less strain and fatigue, for the reason that they are not burdened with the red rays which have comparatively little effect in producing vision but fatigue the eye through their heating action.

(4) THE COOPER HEWITT TUBE LAMP IS THE ONLY COMMERCIAL LIGHT-SOURCE THAT DOES NOT DAZZLE THE EYES WHEN USED WITHOUT ANY ACCESSORY FOR DIFFUSING ITS LIGHT. At the same time it produces a comparatively larger total quantity of light, which it distributes broadly but below its own level. The lamp can thus be hung at any distance above the eye up to forty feet. This fact, together with its low intrinsic brilliancy, enables it to be so installed as to practically remove all glare and to produce a general illumination that is the full equivalent of daylight for ALL purposes, and in many cases actually better than daylight. Where Cooper Hewitt Lamps are properly installed experience has shown that THE OUTPUT PRODUCED UNDER THEIR LIGHT IS ALWAYS FULLY EQUAL, BOTH IN QUANTITY AND QUALITY, TO THAT PRODUCED BY NATURAL LIGHT, AND IN CASES SUPERIOR.

(5) From the fact that the Cooper Hewitt lamp produces neither glare nor sharp, black shadows it affords the greatest protection possible against industrial accidents.

(6) Since the intrinsic brilliancy of the tube is not sufficiently high to produce glare when seen directly, it follows that IT CANNOT PRODUCE GLARE BY DIRECT REFLECTION. There is no annoying glitter from polished or shiny surfaces where Cooper Hewitt lights is used.

(7) The COOPER HEWITT LAMP REQUIRES THE LEAST ATTENTION and the least cost for repairs and upkeep, of any electric light-source, and is also the cheapest to operate, that is, consumes the least electric current of any light-unit that can be considered suitable for industrial illumination.

THE COOPER HEWITT QUARTZ LAMP is a new and distinct form of lamp using glowing vapor of mercury as the light-source. It differs in construction from the standard, or glass-tube lamp, in using a very short tube of pure fused silicia—so-called quartz glass—which admits of a much higher temperature in the mercury vapor, with consequent higher physical efficiency. The intrinsic brilliancy is likewise increased, and some red rays are produced. For this reason the Quartz Lamp is used for the illumination of large spaces, such as yards and sheds, and the larger buildings in the heavy industries. For these purposes its remarkably higher efficiency, and ability to run for months without "trimming," or attention of any kind, give it all the advantages that the standard glass tube lamp possesses for the more exacting industrial operations.

Artificial Illumination Better Than Daylight.

It has been so long the habit of manufacturers to count upon a reduction in both quality and quantity of output during the time artificial light must be used, and to consider many classes of work impossible of performance except under daylight, that even the claim of full equality with natural light is received with incredulity. To claim superiority therefore borders upon the fantastic.

A moment's thought should be sufficient to remove this long established prejudice. It is the particular business of science to improve on nature. Every person who wears glasses is a living example of the successful accomplishment of this purpose. If the human eye is therefore so generally in need of improvement, why may not science produce a light that is better for certain uses than the light of the sun? Not only is this a perfectly fair question, but it is one that has been unequivocally answered in the affirmative. The following cases have been selected as interesting proofs of this fact.

METAL STAMPING. A large stamping works producing cooking utensils operated one of its departments on two shifts, one of ten hours during the day, and one of twelve hours during the night. The crews were changed from night to day fortnightly. A greater production per machine, or unit of equipment, was turned out during the ten hour day shift than during the twelve hour night shift, and this occurred irrespective of the crew working. Illumination was by filament lamps. An increase in the number of these did not increase the production. Cooper Hewitt lamps were then installed, and within a short time the production from the night shift exceeded that of the day shift. Furthermore, while accidents were frequent under the ordinary illumination there have been but two accidents in this department within the last two years, although the work is naturally hazardous.

FIREARMS MANUFACTURING. One of the largest manufacturers of small arms in this country, which has been running night and day for a number of months past, equipped its plant throughout with Cooper Hewitt light. A record kept of the work turned out on a profile machine showed that 90 pieces were turned out during the ten hour daylight shift, and from 75 to 80 pieces during the night shift under ordinary electric light. With Cooper Hewitt lights 105 pieces were turned out during the ten hours of night shift. This ratio was maintained irrespective of the workmen.

MANUFACTURING STEEL SPRINGS. A plant producing steel springs for vehicles and similar uses is operated on a three shift day, with each crew changed weekly. The production of the night shift is invariably greater than that of the day shift. The "personal equation" is thus eliminated, demonstrating that the difference is due to the light.

Steel tempering. One of the best known watch factories uses Cooper Hewitt light exclusively in the spring tempering department, finding both the quantity and quality of product increased over that produced under daylight. This has been a common experience in other lines of manufacture where the tempering of steel is an important part. The particular colors by which the temper of steel is judged are rendered much more distinct under Cooper Hewitt light than under daylight.

Brazing. It has been found that the molten spelter can be distinguished very plainly from the red hot steel or iron in the process of brazing, which can therefore be carried on much more surely and expeditiously under this light.

Silk weaving. In one of the leading silk mills in the East, the foreman found that weavers would draw down the window shades and ask that the Cooper Hewitt lamps be turned on. As this seemed an extravagance the foreman naturally remonstrated. On learning that the weavers could turn out more and better work, however, under Cooper Hewitt light, their requests were granted, except during the hours of bright sunshine.

Inspection. It is in the detection of imperfections in both the metal and textile industries that the superiority of Cooper Hewitt light was most quickly and positively exhibited. In the inspection of textiles, spots and discolorations, and the defects in the weave must be looked for. In both of these cases Cooper Hewitt light has been found to surpass daylight, in the former case permitting more than 100% increase in efficiency. This is due to the greater distinctness of the discolorations produced by the Cooper Hewitt light. The same principle is successfully applied in the grading of sugar in the refineries, and in the sorting of ivory in the manufacture of piano keys. In fact, it holds in all cases where minute differences in shades of white form the bases of grades or qualities.

As to the equality of Cooper Hewitt light compared with daylight illumination for industrial purposes, a single statement will cover the entire question: In no case has it been found that the efficiency of labor performed under Cooper Hewitt light is in the slightest degree inferior to that performed under the best daylight conditions.

Explanation of Terms Used in Illuminating Engineering.

CANDLE POWER. The real significance of the term candle-power is often misunderstood. Such misconceptions will be avoided by considering that intensity of light expressed in candle power applies only to a BEAM OF LIGHT entering the eye, and does not MEASURE the total output, or QUANTITY of light produced by the light-source. Actual light-sources do not give out beams of equal candle-power intensity in all directions. An intensity of unit candle-power is that of the beam of light received by the eye when the candle-flame is on the same level with the eye: i. e., it is the HORIZONAL BEAM that is taken as the STANDARD. The direction in which the light-source is viewed must therefore be stated or understood to give candle-power measurements a definite value.

THE MEASUREMENT OF LIGHT AS A QUANTITY (volume, or flux) is accomplished by introducing area of surface as a factor: i. e., by measuring the amount of ILLUMINATION it can produce, and is therefore the product of the intensity of the illumination by the area illuminated. Intensity of ILLUMINATION is the intensity of the light AT THE SURFACE upon which it falls, and therefore depends upon the DISTANCE of the surface from the light-source, in accordance with the inverse square law.

FOOT-CANDLE. When a light of unit intensity—(1 c.p.) falls upon a SURFACE at UNIT DISTANCE (1 foot) it produces an illumination of unit intensity, called a FOOT-CANDLE.

LUMEN. A UNIT AREA of surface (one square foot) illuminated with a UNIT INTENSITY of illumination requires a unit QUANTITY (flux) of LIGHT; this unit is called the LUMEN.

LUX. The intensity of illumination produced by a light of 1 c.p. at 1 meter distance is called a meter-candle, also LUX.

MEAN SPHERICAL CANDLE POWER is a term formerly in general use for comparing quantities of light. The unit 1 m.s.c.p. is the quantity of light required to produce an illumination of 1 foot-candle over the surface of sphere of 1 foot radius, and is therefore equal to 4 (12.5) lumens.

INTRINSIC BRILLIANCY. Since every point of a luminous surface radiates light, the intensity of the BEAM of light from a measureable surface will depend upon the area of the surface and the intensity of the light from an element (point) of the surface. The RATIO of the INTENSITY of LIGHT to the AREA of SURFACE is called INTRINSIC BRILLIANCY. The ratio is usually expressed in candle-power per square inch.

SURFACE BRIGHTNESS is the ratio of the intensity of light REFLECTED from an illuminated surface to the area of the surface.

THE ORGANS OF VISION consist of two sets of apparatus; the EYE, which is an OPTICAL INSTRUMENT containing exactly the same elements as a photographic camera, viz., a convex lens, a stop, or diaphragm, a sensitive surface for receiving the image produced by the lens, and a means of focusing images on this surface; and the OPTIC LOBES of the brain, with their nerves connecting with the retina, by which the physical and chemical action of the light is transformed into the SENSATION of vision.

VISUAL ACUITY. The essential conditions for clear and distinct visual sensation are a SHARPLY DEFINED IMAGE on the retina, with all the GRADATIONS OF LIGHT AND SHADE clearly produced. Distinctions of color are of little importance for practical purposes, as is shown by the fact that persons who are color blind do not find it a serious handicap. Light having a full spectrum does not give as sharply defined images as light that is of simpler color composition. The SHARPEST IMAGES are produced by light in the YELLOW and GREEN regions of the spectrum.

GOOD ILLUMINATION. When the action of the light received by the eye produces clear and distinct sensations, which the mind can act upon without question or delay, and does not unduly strain or fatigue the muscles of the eye or the nerves and brain-cells, then the illumination is good; to the extent that it fails in any of these respects it is poor. Conditions of illumination which are prejudicial to good vision are:

GLARE, produced by light of excessive brilliancy from small surfaces in the field of vision, usually bare light-sources or direct reflections of them. Corresponds to halation in a photograph.

TOO MUCH OR TOO LITTLE GENERAL BRIGHTNESS, caused by excessive or insufficient lighting. Corresponds to over and under exposure in photographs, the former giving too great, and the latter too little contrast in light and shade.

LIGHT CONTAINING AN UNDUE AMOUNT OF INVISIBLE RAYS; the red and infra-red rays overheat the retina, causing fatigue. Violet and ultra-violet rays produce destructive chemical action in the retinal cells, which prevent their normal functioning. Corresponds to "solarization" in photography.

LIGHT FROM THE WRONG DIRECTION; distorts perspective and relief, giving an unnatural appearance to objects.

LIGHT FROM A SINGLE SMALL SOURCE; gives silhouette effects, black shadows and white high-lights without detail.

LIGHT FROM TWO OR SEVERAL SMALL SOURCES; gives cross shadows, which are confusing to the visual sense.

THE EFFICIENCY OF A LIGHT-SOURCE is the ratio of the quantity of light produced to the energy consumed. The most efficient light-sources known at the present time do not have an efficiency of more than ten per cent.

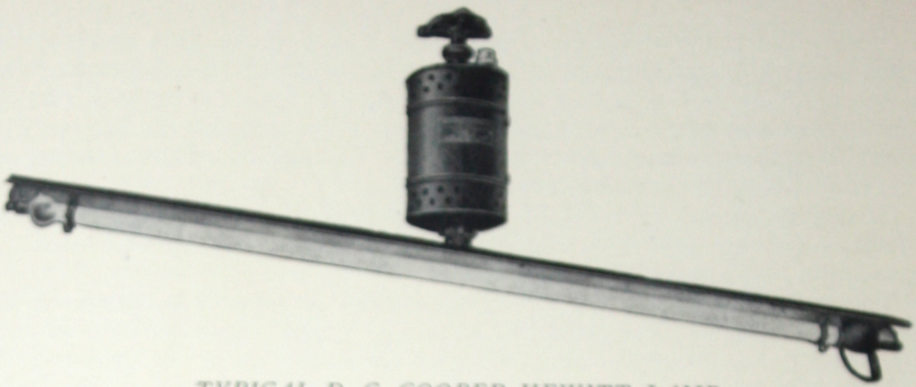
EFFICIENCY OF ILLUMINATION is of two kinds: PROXIMATE efficiency, and ULTIMATE efficiency. The former is the ratio of the light falling upon the objects intended to be illuminated to the total quantity of light produced. A theoretical plane thirty inches from the floor is generally taken as the surface intended for illumination. The quantity of light falling on this plane is commonly called "LUMENS EFFECT'VE."

THE ULTIMATE EFFICIENCY of illumination is the degree to which it fulfills all the purposes for which it is produced. While it cannot be measured mathematically it is of greater practical importance than proximate efficiency. This is especially true in

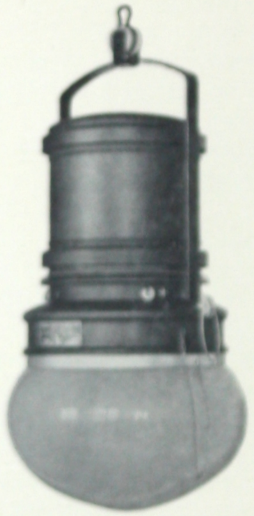
INDUSTRIAL LIGHTING, which includes all cases where illumination is used to expedite manual labor. The efficiency of labor is largely influenced by the character of the illumination by which it is performed. Muscular action necessarily FOLLOWS perception; hence imperfect visual impressions retard motion and impair the accuracy of its application. Ordinary artificial illumination usually reduces the output of labor from ten to twenty per cent.

PRODUCTION CURVES. The ultimate efficiency of artificial illumination is best shown by a curve formed by plotting the output of an individual operative, or of a number of operatives performing the same task, against the successive periods of time throughout the twenty-four hour day. The theoretically perfect production curve is a straight line, or "flat curve," showing no change in output on account of change from the best daylight illumination to artificial illumination.

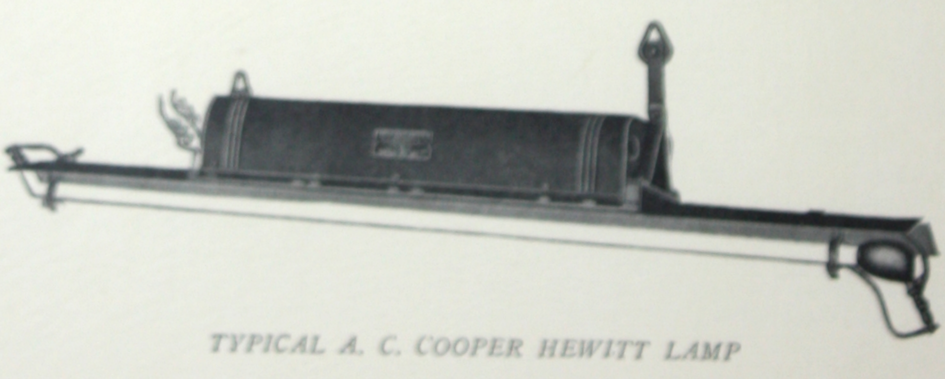
COOPER HEWITT LIGHT INSURES A "FLAT PRODUCTION CURVE." This has been demonstrated by twelve years' use in every branch of industrial lighting. It is attributed to the fact that the Cooper Hewitt lamp is free from glare, and that the light contains no red rays, which overheat the retina and reduce the sharpness of the image, thereby producing mental and physical fatigue. Cooper Hewitt light has been found to surpass daylight for many purposes where particularly sharp vision is required.



TYPICAL D. C. COOPER HEWITT LAMP



COOPER HEWITT QUARTZ LAMP



TYPICAL A. C. COOPER HEWITT LAMP

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